Building Research Establishment Digest

CI/SfB (64·3) (M)

DIGEST 193

September 1976

Loudspeaker systems for speech

Loudspeaker systems tend to have a bad reputation although they are capable of functioning perfectly satisfactorily. Shortcomings can be avoided if installations are well designed, well installed, well maintained and properly used. This digest reviews the general principles that should be followed to achieve satisfactory performances. It also outlines the types of system available to help those generally responsible for the design and use of rooms but who are not directly concerned with the technical details; these will be the concern of the equipment supplier. It does not discuss loudspeaker requirements for music: any auditorium where music reproduction is of importance will usually warrant an acoustical consultant and his brief would include the loudspeaker system.

In this digest, the word 'speaker' means the person speaking as opposed to the loudspeaker; a 'speech reinforcement system' is defined as one that has the speaker and the loudspeaker in the same room whilst a 'public address system' has them in separate rooms. The design principles are the same for both, except that there is no feed-back problem with a public address system and there is no need for the sound to appear to be coming from the person speaking: this is desirable with some speech reinforcement systems. Especially in a large room, a loudspeaker system helps speech in one or both of two ways: it makes the speech louder so that it can be heard above the background noise (eg traffic noise) and it can mitigate the effect of the reverberant sound on the intelligibility of speech.

As described in Digest 192, the direct sound from any source will fall off with distance according to the inverse square law, ie a drop of 6 dB for every doubling of the distance. The intelligibility of speech depends on this direct sound being louder than both the background noise and the reverberant sound, both of which are roughly at the same level throughout the room. Feed-back limits the loudness of speech reinforcement systems: if the limit is exceeded, sound from the loudspeakers is picked up by the microphones, amplified and re-emitted from the loudspeakers; the sound gets louder each time round the circuit and results in howl. The effect can be minimised by using directional microphones and loudspeakers and, as far as practical, positioning them so that their least sensitive sides are towards

Prepared at Building Research Station, Garston, Watford WD2 7JR
Technical enquiries arising from this Digest should be directed to Building Research Advisory Service at the above address.

each other. The loudness of public address systems is limited by the size of the amplifiers and the loudspeakers. Keeping the direct sound above the reverberant sound (and limiting feed-back in speech reinforcement systems) depends mainly on the design and position of the loudspeakers; this is the most difficult part of designing a system for speech.

Any repetition of the sound which arrives at the listener not more than about 35 milliseconds after the arrival of the direct sound blends with the direct sound and is a help to the intelligibility. Any repetition coming later than this hinders the intelligibility, and the louder the repetition is relative to the direct sound, and the further behind it is, the more it hinders. When speech is being reinforced by one loudspeaker, this should be placed so that the sound from it arrives at the listener within 35 milliseconds of the sound from the speaker. This means that the distances from speaker to listener and from loudspeaker to listener should not differ by more than about 10 m.

If the listener is further from the loudspeaker than from the speaker, the sound from the loudspeaker will reach the listener later than the sound from the speaker and even if the loudspeaker sound is as much as twice as loud as the sound from the speaker, all the sound will appear to be coming from the speaker. This is known as the 'precedence' or 'Haas' effect and is important where it is desirable to maintain some illusion of reality. To sum up: for intelligibility the various sounds should arrive within 35 milliseconds of each other; for realism the sound from the speaker should arrive first.

There are two main classes of speech loudspeaker systems, low-level and high-level (level refers to loudness of the output from each loudspeaker and not to their height above the floor).

Low-level systems consist of a large number of smallish loudspeakers distributed throughout the room usually just above head-height. No listener is very far from a loudspeaker and all get adequate direct sound from the one nearest. If it is physically possible to have loudspeakers close enough to everyone, the acoustics of the room hardly affect the intelligibility of the speech. There have been systems where every seat has had its own loudspeaker but this is not always possible or convenient. When loudspeakers have to be, say, 10 m or more away from the listeners (if they must be fitted to the walls for example) this type of system has limitations partly because the nearest loudspeaker may now be too far away to be louder than the reverberant sound and partly because the sounds arriving from different loudspeakers may be of much the same loudness but different enough in arrival times to hinder intelligibility. In all low-level systems the sound will be coming from the loudspeaker nearest to the listener and not from the speaker; there is no realism. This may not matter but the overall sound of a lot of small loudspeakers can be rather unpleasant.

With low-level systems, and for speech from fixed microphone positions, feed-back is usually not much of a problem because, although the loudspeakers are not usually directional, they are operating at a low volume and can be kept far enough away from the microphone. If microphones are to be used from anywhere in the room, eg at a conference, feed-back may be more of a problem and it may be necessary to switch off the loudspeakers close to the microphone in use.

High-level systems use only a few loudspeakers,* perhaps only one, operating at a higher sound output. The main advantages over low-level systems are that they may be easier to install (fewer electrical connections are necessary) and it is much easier to maintain realism. Greater care in design is needed than with low-level systems for adequate loudness and intelligibility over the whole audience area.

* Ordinary loudspeakers are rarely used in high-level systems because they are directional only at the higher frequencies. Their use, therefore, introduces feed-back problems and they are only a little help in keeping the direct sound above the reverberant sound. This help comes from placing the loudspeakers higher than the speaker; the direct sound from the speaker is at grazing incidence over the heads of the audience and gets attenuated at a greater rate than the inverse square law; the sound from the loudspeaker is not so much attenuated.

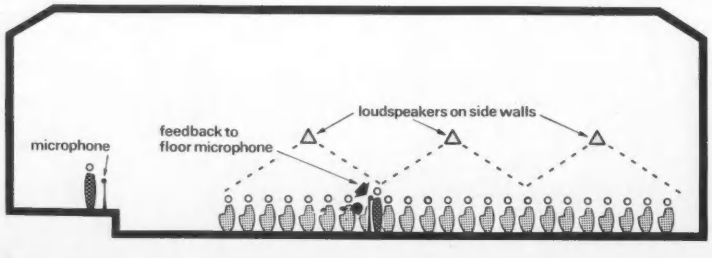
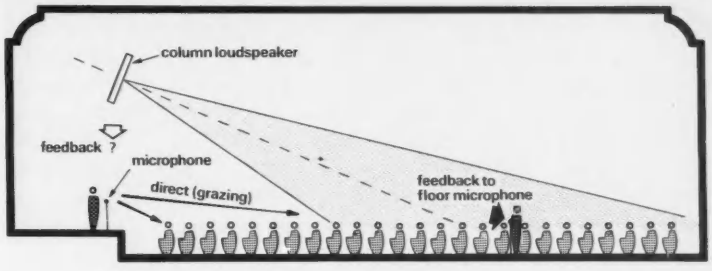


Fig 1 Low-level loudspeaker system

Fig 2 High-level loudspeaker system



The majority of high-level systems use directional loudspeakers and, although there are several types, the most common is the loudspeaker column. This consists of several ordinary loudspeakers mounted vertically one above the other which has the effect of concentrating most of the sound in the vertical plane into a beam at right angles to the column whilst having no effect in the horizontal plane (some columns are designed to be directional in the horizontal plane as well as in the vertical to reduce feed-back). The result is something like a fog lamp beam: narrow in the vertical plane and broad in the horizontal plane.

This directionality benefits in two ways. Firstly, feed-back can be minimised by positioning the loudspeaker so that the microphone is out of the main beam. Secondly, the main beam of sound is directed at the audience and is there largely absorbed before it can become reverberant sound. Thus, the direct sound level is kept well above the reverberant sound level. A minor advantage is that because of this concentration of sound, less power is required from the amplifiers and the loudspeakers.

Obviously the columns must be carefully positioned so that the sound is directed most usefully. This usually means that the base of the column is slightly above audience head height (by not more than about a metre) and tilted forward about 5 to 10 degrees. The centre of the beam of sound should hit the audience at about two-thirds of the way back. This ensures that most of the audience is in the beam and that there is some compensation for the inverse square law reduction.

Depending on the design of the room it may be necessary to move the column higher and tilt it more forward. This will tend to reduce feed-back but the column must be less directional or the whole of the audience will not be in the beam. The directionality of a column depends on its length relative to the wave length of sound: the longer the column the more directional it is for a given frequency. This means, of course, that a column gets more directional the higher the frequency and this is a disadvantage: the column may not be long enough to be sufficiently directional at low frequencies and be too directional at higher frequencies. Columns are available which overcome this disadvantage but they are more expensive; more sophisticated columns are becoming available which do not need to be tilted forward.

The number of loudspeaker columns necessary will obviously depend on the size of the room and how reverberant it is. For speech from one end of the room only, one loudspeaker column to one side of the room at that end will normally be enough, but listeners near the front on the other side of the room will not hear much loudspeaker sound. A column may be needed on each side in wider rooms. If one column is used, it should for realism be positioned slightly further back (1·5 m) than the speaker, at the risk of increasing the feed-back problem because the column will be only slightly directional in the horizontal plane, ie radiate less to the sides and back than to the front.

If a column is used on each side realism can be achieved only by introducing delays in the electronics.

If two columns are used, they must be in phase but there will always be a slightly odd effect for listeners on the longitudinal centre line of the room because, due to the Haas effect, they will hear all the sound apparently coming from one side or other of the room, depending on which way they lean their heads.

In a fairly small room, seating, say, up to about 200 people, and with a reasonable reverberation time (not more than 1·5 seconds) a column about 1·5 m long will be suitable. For larger rooms and longer reverberation times, a column 2 m or even 3 m long may be necessary. It is impossible to be more specific than this, because of the many types of column available.

With any type of system, the microphone should be as close to the speaker as possible to reduce the amplification necessary and the chance of feed-back. For speech from a fixed position the microphone can obviously be on a stand. A halter microphone has the advantage of keeping a constant distance between the mouth and the microphone, (although there is a noticeable difference in quality when moving the head down to look at notes and up to look at the audience or turning the head to one side). However, the speaker is free to walk around or to use chalk boards etc. With the microphone on a stand, the speaker cannot move away from the stand without losing practically all aid from the loudspeaker system. Even moving the head about so that the distance from the microphone varies between say, 100 mm and 300 mm will result in the amplified sound varying by a distracting factor of two in loudness.

If there has to be speech from the floor, microphones are unavoidably in the main beam and it is necessary to rely on the directionality of the microphone to reduce feed-back, ie to use a microphone which has the least sensitivity at its back.

Any system must be well maintained. Microphones are vulnerable to mechanical damage; amplifiers can develop intermittent faults; loudspeakers are probably the most reliable part. For a large system it is probably wise to have a maintenance contract with the supplier, although with the simple systems described in this digest there should be little trouble with good quality equipment. Ideally, there should be a trained operator to adjust the volume of the system to suit different speakers and to guard against feed-back if, for example, the microphone is moved.

Finally, no system will turn mumbling speech into clear speech and the speaker must speak up, speak clearly, keep a fairly constant distance from the microphone, and not vary much in loudness from word to word, or even from syllable to syllable. The more reverberant and noisy a building, the more important it is that the speaker should remember these points. Notes to guide preachers in reverberant churches were written some years ago by Mr Hope Bagenal.

His advice, quoted here in part, cannot be improved upon: *'A good microphone technique is one that proceeds at a slow pace; maintains an even distance from the microphone; does not greatly vary the loudness. Of these, going slow is very important indeed: no amplification system, in a church having a long reverberation, can enable a preacher to be heard if he goes too fast. Some slight variation of loudness is permissible in order to avoid monotony, but the microphone cannot deal with the shout or the dramatic whisper: the technique is more a reading than an oratory . . . it is the syllable, not the word which is the unit of sound: hence in reverberant conditions a slowness of separate syllables is required rather than long pauses between words, or between sentences . . ..'*

Department of the Environment **Building Research Establishment**

© *Crown copyright 1976*

Published by Her Majesty's Stationery Office and printed in England by Benham and Company Limited, Colchester.
Single copies 7p each. Annual subscription inclusive of postage £2.25 for 12 monthly issues and new editions of earlier Digests.
Quantity rates (excluding postage) for bulk supply of any one Digest: 25 for £1.47, 50 for £2.31, 100 for £4.20.

Dmd. 496352 K628 9/76 ISBN 0 11 724089 3